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THE CONCEPT OF USING THE DEEP RIVER AND KERGUELEN NEUTRON MONITORS AS "FLAGSHIP" STATIONS FOR GROUND-LEVEL SOLAR COSMIC RAY EVENTS

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Abstract

Stations with a cutoff rigidity of approximately 1 GV have asymptotic cones of acceptance that sweep around the globe near the equatorial plane. Therefore these stations are the most likely to record at least part of every solar cosmic ray increase. Neutron monitors with asymptotic cones of acceptance along the interplanetary magnetic field lines toward the sun will probably record the highest increase during an anisotropic solar cosmic ray event. We suggest that the Deep River, Canada and the Kerguelen Island neutron monitors, located in opposite hemispheres approximately 180 degrees apart, are ideally situated for recording these unusual solar events and should be designated as "Flagship" monitors to provide a preliminary picture of any event for the cosmic ray community.

Concept. The concept of "Flagship" stations is taken from the geomagnetic aa index in which two antipodal stations are used to derive a daily index of activity that represents the magnetic conditions for the day. An extension of this concept is to use the data from two strategically placed neutron monitors to typify transient cosmic ray phenomena, especially solar cosmic ray events. Inspection of the distribution of the world-wide network of cosmic ray neutron monitors shows that there exists two stations which are approximately antipodal, have approximately a 1.1 GV geomagnetic cutoff, a rigidity where the maximum response of an isotopic solar cosmic ray event might be expected, and have wide asymptotic cones of acceptance which essentially sweep around the globe. These stations are Deep River in Canada (46.10N, 282.50E, a 48-NM-64 at geomagnetic cutoff of 1.15 GV) and Kerguelen Island located in the Indian ocean (49.35S, 70.22E, an 18-NM-64 located at geomagnetic cutoff of 1.14 GV).

Asymptotic Cone of Acceptance. As a cosmic ray comes under the influence of the earth's magnetic field, its orbit becomes a complex function of particle mass, momentum, and charge. The calculation of the amount of geomagnetic bending a particle undergoes in the geomagnetic field is generally obtained with the aid of high-speed digital computers. The cosmic ray particle is traced back through the magnetic field in a point by point integration to a position far removed from the earth, say to the boundary of the magnetosphere, and then the asymptotic direction in interplanetary space is calculated. These asymptotic directions over the rigidity range applicable to relativistic solar proton events form a definitive cone of acceptance. The range of directions in interplanetary space that cosmic rays must have in order to arrive at a specific point at the top of the atmosphere above a specific station is referred to as the asymptotic cone of acceptance (McCracken et al., 1968). Within this cone the geomagnetic field also has a focusing effect such that the asymptotic directions of ap-

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proach for particles vertically incident at the top of the atmosphere typify the cone for most of the possible allowed zenith and azimuth incidence angles at a specific location.

Very high-latitude neutron monitors scan a cone of acceptance that is relatively narrow. Recognizing this, one finds that it is possible to use a network of high latitude stations to monitor continually the particle flux as a function of time near the ecliptic plane. Lower latitude stations have an asymptotic cone of acceptance that circumscribes the entire equatorial plane and, therefore, the response is more of a function of the interplanetary anisotropy than local time. By an extremely fortuitous geophysical position, the neutron monitors at Deep River, Canada and Kerguelen Island are in excellent locations for monitoring changes in the cosmic radiation throughout the entire day since the geomagnetic cutoff rigidity of about 1 GV coincides with the approximate atmospheric cutoff resulting in a wide asymptotic cone of acceptance that circles the entire earth.

Calculation of the Response of a Neutron Monitor to a Solar Particle Event. There is a unique set of values for parameters defining the solar proton differential rigidity spectrum, anisotropy, and apparent source direction near the earth that, when transmitted through the asymptotic cone of acceptance for each neutron monitor and through the neutron monitor specific yield function, will generate the observed increase for any location on earth. Calculations of the relative increase expected at any neutron monitor from a specified particle spectrum, anisotropy and apparent source direction utilize the following equation:

$$I = \int_{R_c} J_{allowed}(\alpha,R)\ S(R)\ G(\alpha,R)$$

where I is the computed response of the neutron monitor to a flux of solar protons with rigidity above the cutoff rigidity, R_c, $J_{allowed}(\alpha,R)$ is the differential flux in the interplanetary medium at pitch angle α and rigidity R that is allowed through the asymptotic cone of acceptance, S(R) is the neutron monitor specific yield as a function of rigidity, and $G(\alpha,R)$ is a function that describes the anisotropic pitch angle distribution. We have used an exponential form to describe the pitch angle distribution based on a simplification of the work of Beeck and Wibberanz (1986). Our form is

$$G = \exp \int \frac{1 - u^2}{\langle u \rangle}$$

where u is the cosine of the pitch angle and <u> is a constant relating to the "average" anisotropy. We have found that this form is clearly superior to the Gaussian pitch angle distribution used in earlier work (Smart et al., 1971, 1979; Shea and Smart, 1982). Samples of these pitch angle distributions are shown in Figure 1.

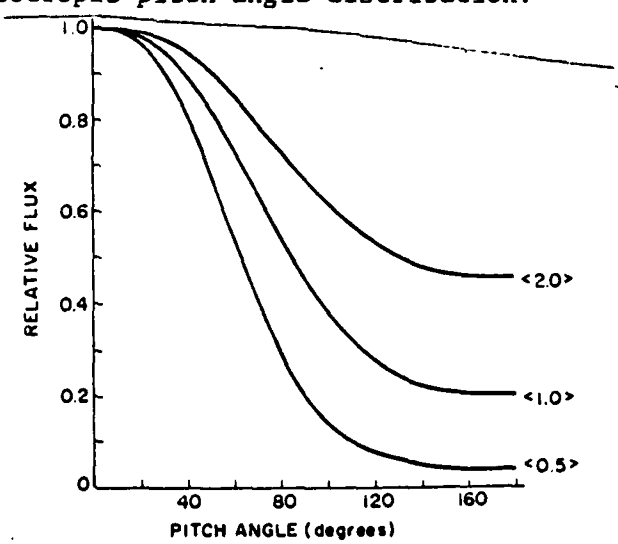


Figure 1. Pitch angles distributions for various anisotropies.

To a first approximation, the maximum response of a neutron monitor station to a ground-level cosmic ray event occurs at about 09 hours asymptotic time. Asymptotic time is the time equivalent of the angular difference between the asymptotic direction in space and the projection of the sun-earth line beyond the earth (i.e. midnight line). Since this concept is difficult to visualize, it is more useful to specify the response in universal time. In Figure 2 we illustrate the calculated response of the Deep River (indicated by the heavy line) and the Kerguelen neutron monitors to various anisotropic solar particle fluxes as a function of universal time. The relative responses of each station have been normalized so that the maximum possible increase is equated to 100%. The calculated maximum in response for the Deep River neutron monitor is between 0600 and 0900 UT; the calculated maximum for Kerguelen is approximately midnight UT. The result is that between these two detectors at least one of them will have a response to almost any type of relativistic solar proton event.

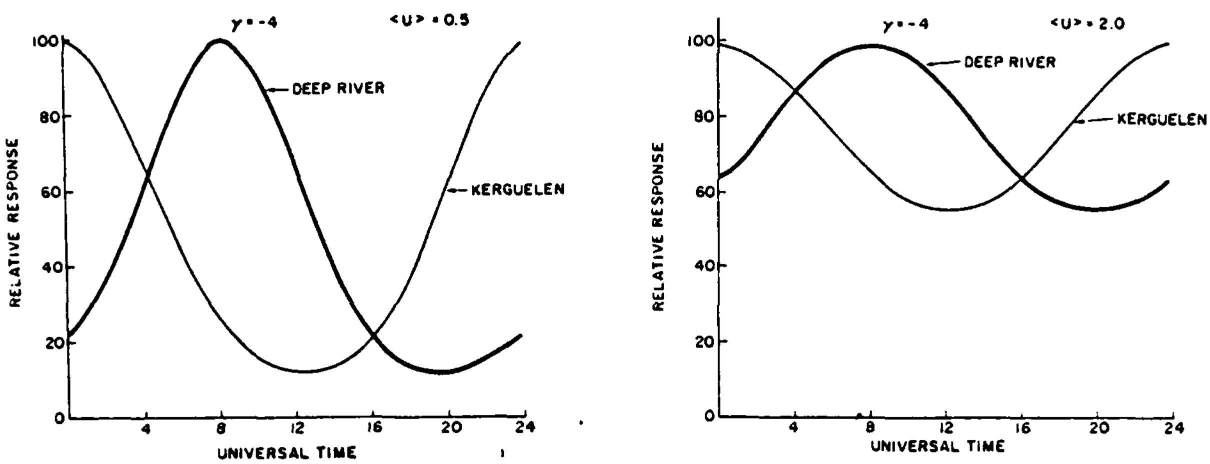
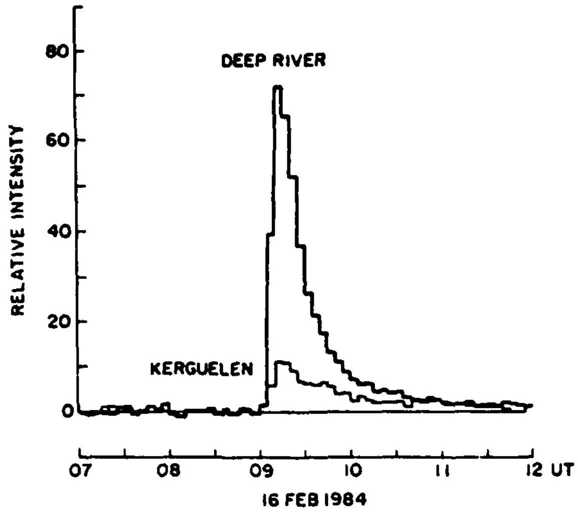


Figure 2. Calculated response of the Deep River (heavy line) and Kerguelen neutron monitors to two different flux anisotropies. Left: a very anisotropic flux (<u> = 0.5). Right: a mildly anisotropic flux (<u> = 2.0).

<u>Discussion</u>. Inspection of Figure 2 illustrates that for highly anisotropic solar particle fluxes the response of the Deep River and Kerguelen neutron monitors is local time dependent. However, the likelihood that the Deep River and Kerguelen neutron monitors would not detect a high-energy solar proton event is very small regardless of when the event occurs, provided there is a sufficient flux of particles with E > 450 MeV. Inspection of these curves indicates that this type of solar particle event will be detected at any local time of the day. We have selected two sample events that have anisotropies approximately equivalent to that in the left of Figure 2 to illustrate the detection capabilities of this pair of "Flagship" stations. These increases are shown in Figure 3.



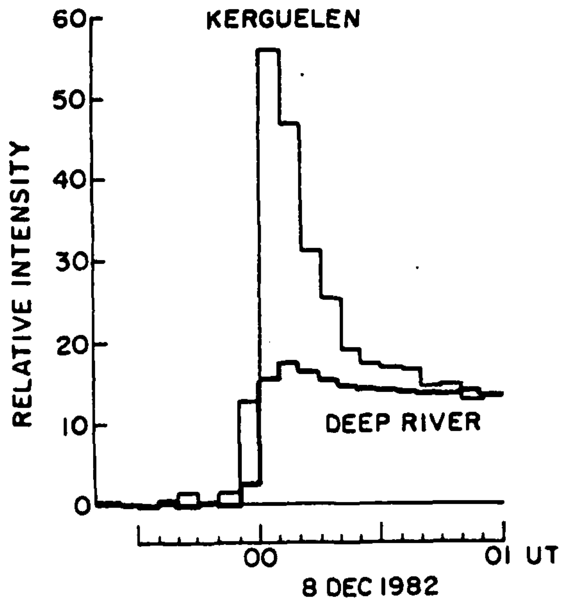


Figure 3. Left: Relative response of the Deep River (heavy line) and Kerguelen neutron monitors to the anisotropic solar cosmic ray flux of 16 February 1984; this event occurred at the optimum time for a maximum response at Deep River. (Note the relative ratios of the observed increase with the calculations in Figure 2.) Right: Relative response of the Kerguelen and Deep River (heavy line) neutron monitors to the initially anisotropic solar cosmic ray flux of 8 December 1982; this event occurred at the optimum time for a maximum response at Kerguelen.

Conclusions. In this paper, we have calculated the response of the Deep River, Canada and Kerguelen Island neutron monitors to a high-energy ($E >$ 450 MeV) anisotropic solar proton flux as a function of local time and anisotropy. From these results, we find that there is a daily variation in the neutron monitor response to an anisotropic solar cosmic ray event. However, a combination of "Flagship" stations such as the Deep River and Kerguelen stations would allow detection of even short-lived extremely anisotropic solar cosmic ray increases at any local time throughout the day.

References.

Beeck, J. and Wibberanz, G.: 1986, Astropy. J., 311, 437.

McCracken, K.G., Rao, U.R., Fowler, B.C., Shea, M.A., and Smart, D.F.: 1968, Cosmic Rays (Asymptotic Directions, etc.), Chapter 14 in Annals of the IQSY, 1, 198, The MIT Press, Cambridge.

Shea, M.A., and Smart, D.F.: 1982, Space Science Reviews, 32, 251.

Smart, D.F., Shea, M.A., and Tanskanen, P.J.: 1971, 12th International Cosmic ray Conference, Conference Papers, 2, 483.

Smart, D.F., Shea, M.A., Tanskanen, P.J. and Humble, J.E.: 1979, 16th International Cosmic ray Conference, Conference Papers, 5, 238.